Indian J. Phys. **70A** (5), 655–658 (1996)

IJP A
— an international journal

Determination of zeta calibration constant against a corning dosimeter glass of 36 PPM natural uranium using age-standard apatites

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Received 15 December 1995, accepted 14 March 1996

Abstract : Zeta calibration of standard dosimeter glass of 36 PPM natural uranium (corning) has been made against age standard apatite minerals from Mt. Dromedary Complex (98 7 ± 0.6) Ma and Fish Canyon Tuff (27.77 ± 0.08) Ma The result is $\zeta = 1112 \pm 21$.

Keywords : Fission track dating, zeta calibration, geochronology

PACS Nos. : 29.40.Gx, 91.35.Nm

The spontaneous fission decay rate λ_f of U-238, (which enters into the age equation used in Fission Track Dating (FTD)) given by various authors ranges from 5.3×10^{-17} Yr^{-1} [1] to 12×10^{-17} Yr^{-1} [2]. This causes considerable uncertainty in the dates estimated [3].

Another important parameter causing uncertainty in mineral ages is the neutron flux ϕ. It is measured from the relation $\rho_d = B\phi$, where ρ_d is the track density in standard glass and B is a constant. Determination of B requires an accurate determination of uranium content in standard glass.

In order to avoid these problems Hurford and Green in 1982 [4], proposed to calibrate the fission track method of dating against minerals of standard known age as determined by several other methods. Several scientists [4–9] have done pioneering work in this field.

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In this technique, the parameters whose magnitudes are in doubt, are combined into one calibration factor termed as zeta (ζ) given by the equation :

$$\zeta = \frac{\rho_t}{\lambda_d g \rho_s \rho_d} \left[\exp\left(\lambda_d T_s\right) - 1\right] \tag{1}$$

where ρ_t = Induced track density,

λ_d = Total decay constant of U-238,

T_s = Age of the standard mineral in Ma,

g = Geometry factor (= 1 in present case),

ρ_s = Fossil track density,

ρ_d = Track density in standard glass.

After determining ζ, age T can be calculated from the equation

$$T = \frac{\log\left[\left\{\left(\zeta \lambda_d g \rho_s \rho_d\right)/\rho_t\right\} + 1\right]}{\lambda_d \log e} \text{ Ma.} \tag{2}$$

The constants used in the present work are

$\lambda_d = 1.55125 \times 10^{-10}\ \text{Yr}^{-1}$. [10],

$$\frac{U - 235}{U - 238} = 7.250 \times 10^{-3},$$

$\sigma = 580.2 \times 10^{-24}\ \text{cm}^2$.

The value of ζ was determined with the help of age standard minerals (described in Table 1 below) obtained from Dr. D S Miller of Department of Geology, Rensalaer Polytechnique Institute, Troy, New York.

Table 1. The age standard minerals.

Sample	Mineral	Reference age $\pm 2\sigma$ (in Ma)
84–3 Fish Canyon Tuff	Apatite	27 77 ± 0.08
84–4 Mt Dromedary Complex	Apatite	98.7 ± 0 60

These age standard minerals were some of the minerals used for global inter-laboratory comparison at the Fission Track Dating Workshop, 1984. Miller *et al* in 1985 [11], described the results in which they mentioned Fish Canyon Tuff apatite sample as Sample No. 84–3 and Mt. Dromedary Complex apatite sample as Sample No. 84–4.

The age-standard apatite grains were mounted in epoxy resin, grinded and polished successively in 8μ, 3μ and 1μ diamond pastes. Those were then etched in 6% HNO_2 at

22°C for 30 seconds. The tracks were scanned in an optical microscope and fossil track density ρ_s was determined. Next, the samples along with a piece of standard glass were irradiated in a thermal neutron flux of 10^{13} n/cm^2/sec in the CIRUS Reactor, BARC, Trombay. The Reactor position was IC–2 Self Service Tray Rod. The Cd ratio in gold was 100.

The irradiated samples were again polished and etched under the same etching conditions and scanned for determination of ρ_i, the induced track density and ρ_d the track density in standard glass.

The value of ζ was calculated with the help of eq. (1) The experimental data are presented in Table 2.

Table 2. Determination of zeta constant for the corning dosimeters glass of 36 ppm natural uranium

(A) Sample No. 84–3 Fish Canyon Tuff apatite.

Mineral No	ρ_s 10^6/cm^{-2}	ρ_i 10^6/cm^{-2}	ρ_d 10^6/cm^{-2}	T_s (Ma)	T(Ma) without calibration	ζ
A 31	0 11 (65)	7 13 (4129)	1 5429		25 ± 3	1169 15
A 32	0 08 (55)	5 11 (4010)	1 5429		25 ± 3	1158 90
A 33	0 11 (85)	6 70 (5159)	1 5429	27 77 ± 0 04	27 ± 3	1098 64
A 34	0 09 (80)	5 65 (4859)	1 5429		26 ± 3	1132 44

(B) Sample No. 84–4 Mt Dromedary Complex

Mineral No	ρ_s 10^6/cm^{-2}	ρ_i 10^6/cm^{-2}	ρ_d 10^6/cm^{-2}	T_s(Ma)	T(Ma)	ζ
A 41	0 61 (100)	9 36 (1545)	1 5429	98 7 ± 0 08	106 ± 11	989 13
A 42	0 58 (55)	9 42 (895)	1 5429		99 ± 13	1046 96
A 43	0 57 (105)	10 16 (1880)	1 5429		90 ± 9	1149 02
A 44	0 59 (85)	9 59 (1390)	1 5429		99 ± 11	1047 79
A 45	0 48 (115)	8 90 (2135)	1 5429		87 ± 9	1195 24
A 46	0 53 (125)	9 30 (2185)	1 5429		92 ± 9	1131 13

From the above two tables, the mean value is obtained as $\zeta = 1111\ 83 \pm 21$

The mean value of ζ thus obtained has been used in standardizing various Fission Track Dates obtained earlier in this laboratory Standardization leads to only 5% upward revision of the dates.

Acknowledgments

The authors acknowledge their gratefulness to Prof. D S Miller of Rensalear Polytechnic Institute, New York, for providing the age standard apatite minerals. The Bhaba Atomic

Research Centre, Trombay and Dr. R H Iyer of that organisation are specially thanked for the neutron irradiation facilities provided to us.

Prof. Susumu Nishimura of Kyoto University, Japan is also specially thanked for suggesting this work.

References

[1] K A Petrzhak and G N Flerov *Phys Rev.* **58** 89 (1940)

[2] E K Gerling, Yu A Shkulyokov and B A Makarochkin *Radio Khimiya* **1** 223 (1959)

[3] G Bigazzi *Nucl. Track* **5** 3544 (1981)

[4] A J Hurford and P F Green *Earth, Planet Sci. Lett.* **59** 343 (1982)

[5] A J Hurford and P F Green *Isotope Geosci* **1** 285 (1983)

[6] P F Green *Nucl. Tracks* **5** 77-86 (1985)

[7] S Nishimura and I Mogi *Jour. Geotherm Res. Soc. Japan* **8** 145-164 (1986)

[8] T Tagami *Nuclear Track Radiat Meas.* **13** 127-130 (1987)

[9] T Tagami and S Nishimura *Nucl. Tracks Raadiat, Meas.* **16** 11-14 (1989)

[10] R H Steiger and E Jager *Earth Planet Sci. Lett.* **36** 359, 362 (1977)

[11] D S Miller, I R Duddy, P F Green, A J Hurford and C W Naeser *Nucl. Tracks* **10** 383 (1985)